How LRAD Works

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In November 2005, pirates attacked the cruise ship *Seabourn Spirit* off the coast of Somalia. The pirates were in a small boat, but they had machine guns and rocket-propelled grenades. The cruise ship, on the other hand, had a **Long Range Acoustic Device (LRAD)**.

Many media outlets credited the LRAD with warning off the pirates, leaving the *Seabourn Spirit* unscathed. Some of the coverage was pretty dramatic. News stories described the LRAD as a sonic weapon that fired a beam of sound at the pirates and drove them away.

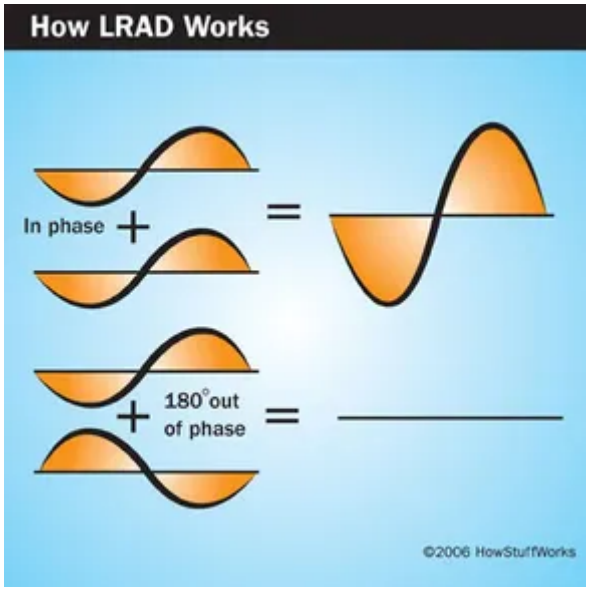
What makes sound a weapon? In this article, we'll review the basics of sound and discuss exactly how the LRAD produces its "beam of sound." We'll also explore LRAD's hailing and warning abilities and other uses for sound.

Noise Levels

The louder a sound is, the more it moves the structures in your ear. The higher its pitch, the faster it moves them. Loud or high-pitched noises can cross the **threshold of pain**, or the point at which a sound is painful. Here's how some everyday sounds compare to the LRAD:

- Normal conversation: 60 dB
- Lawn mower: 90 dB
- Threshold of pain: 130 dB, depending on the person's tolerance
- LRAD maximum continuous volume: 162dB

A Review of Sound and Hearing



Wave addition. (This example uses transverse rather than longitudinal waves because their differences are easier to see.)

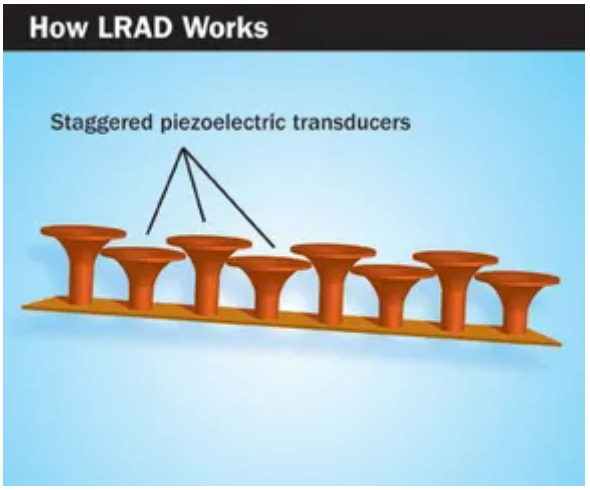
No matter what creates it, sound is always made of **waves**. These waves move through matter, such as air, water or the ground. They interact with the matter (and in some cases with each other) as they go. The animation below will show you the basics of sound waves and how they travel. If you already know how sound waves work, just skip to the next section.

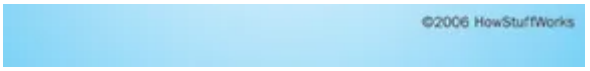
Sound waves can pass through one another without much distortion or change. But in the right conditions, sound waves can change each other dramatically. For example, identical sound waves that are **out of phase** (their compressions and rarefactions are reversed) can cancel one another out. On the other hand, identical waves that are **in phase** combine their compressions and rarefactions, doubling their amplitude.

As sound waves travel, they spread out in all directions in a curved **wave front**. The farther they travel from the source, the more they spread and the quieter the sound becomes. But high-frequency waves don't spread as much as low-frequency waves. Also, waves with long wavelengths generally travel farther than ones with short wavelengths.

There are plenty of other things to learn about sound, but this is what you need to know to understand the LRAD. We'll look at how the LRAD creates sound and takes advantage of these physical properties next.

How the LRAD Unit Works





The LRAD has lots of transducers in a staggered arrangement.

The LRAD's job is to make sound - lots of sound. It produces very loud sound that is audible over relatively long distances. But it's not limited to producing painful noise for use as a weapon. It can also amplify voices or recordings to a level that is loud and clear but not painful or debilitating.

Instead of using one big, moving device to make all this sound, the LRAD uses lots of little ones. A speaker usually uses one rapidly moving diaphragm to make sound. The LRAD uses has an array of **piezoelectric transducers**. A transducer is simply a device that changes one kind of energy into another kind of energy. In this case, it changes electrical impulses into sound.

A piezoelectric material is a substance that is permanently electrically **polarized** -- it has a positively charged side and a negatively charged side. If you apply pressure to a piezoelectric material, it creates an electrical impulse. On the other hand, if you apply an electrical charge to it, its molecules move and it changes shape. Using electrical current from a battery, generator or other source, the LRAD applies electrical charge to lots of piezoelectric transducers. The transducers rapidly change their shape and create sound waves.

Applying a charge to a piezoelectric material causes it to change shape.

All of these transducers are attached to a mounting surface. They're staggered to allow more of them to fit into a smaller space. This helps the LRAD create very loud sounds -- identical waves emerge from the transducers, and their amplitudes combine to create louder sounds.

LRAD and Directional Sound

The back of the LRAD has handles so people can direct the majority of the sound it creates.
PHOTO COURTESY AMERICAN TECHNOLOGY CORP

On the previous page, we looked at how the LRAD creates lots of volume. So that's how the LRAD creates lots of volume. But the sound coming from the LRAD is also relatively **directional**. It doesn't disperse as much as sounds from typical speakers. People behind or next to the device still hear the sound, it isn't as loud. Even outside the beam, the sound can still be loud, so operators and nearby personnel often wear ear protection.

The LRAD uses the phase of the sound waves, the size of the device and the properties of air to create more directional sound:

- The outer transducers are not completely in phase with the inner transducers. The sound waves interact with one another, canceling out some of the outermost waves and making the sound less audible outside of the "beam."
- The device's diameter is larger than most of the wavelengths it produces. This allows the device to create a wave front that's more flat than rounded, keeping the sound from dispersing.
- Air interferes with sound waves as they pass through it. As the

> LRAD's sound waves interact with the air, they create additional frequencies within the wave. Such waves are referred to as **parametrically generated**, and many speakers try to prevent them. The LRAD uses them to create a greater range of pitches and to add volume.

The result is essentially a loudspeaker that can receive input from a microphone, a recording device or a Phraselator translation device. It can then amplify that input, allowing law enforcement, security and military personnel to give instructions and warnings or to clear buildings and disperse crowds. If those verbal instructions don't produce a result, the LRAD can produce a loud warning tone that approaches or passes the threshold of pain.

When used to cause pain or disorientation, the LRAD is a **non-lethal weapon**. Next, we'll look at the pros and cons of using LRAD in this manner.

LRAD 2000x Fast Facts

Basic specs for the LRAD 2000x:

- Range: 8,900 meters (speech)
- Beam width: +/-15° @ 1.0 kHz/-3dB
- Maximum output: 162dB SPL at 1 meter

Pros & Cons of LRAD

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American Technology Corporation (now the LRAD corporation) developed the LRAD after the attack on the USS Cole in 2000. Its original purpose was to help enforce the safe zones around United States military vessels. Using the LRAD's default settings, a ship's crew can warn a craft that it is approaching a military ship and must change course. When used for communication, it's loud and clear but not usually painful. But if the craft doesn't change course, the ship's crew can override the LRAD's default settings. It can then produce a loud, irritating, potentially painful noise that acts as a deterrent. Ideally, the craft would then leave the area without the ship having to use lethal force.

Police and land-based military units have found uses for the LRAD. Using the same principles, authorities can give warnings and instructions that are audible to a large group of people. Law enforcement officials can use the devices to give instructions to large groups of people or order them to disperse, or to use loud sound levels to deter people from entering an area or warn them away.

However, human rights groups and hearing specialists alike have raised concerns about the LRAD. According to the National Institute on Deafness and Other Communication Disorders, any sound over 90 dB can damage a person's hearing [ref]. So the LRAD can threaten the hearing of anyone in its path, regardless of whether there is any wrongdoing, even when used only for communication.

Like stun guns, tear gas and less-lethal ammunition, LRAD can be used in crowd control and other situations as a non-lethal weapon. Non-lethal weapons are somewhat controversial. Human rights groups stress that even though they are less lethal, they are still weapons and have caused deaths in some circumstances. The LRAD in particular has drawn criticism since its effects can be permanent, and non-lethal weapons' effects are supposed to be temporary.

Finally, some people have questioned the LRAD's effectiveness, since wearing simple ear protection can render it useless.

Check out the next page for links with information about sound, the LRAD and other related topics.

Other Uses for Sound

Sound is useful for lots of things besides communication and music. Here are some examples:

- **The "Mosquito"**: Younger people can hear higher-pitched noises than older people. The Mosquito takes advantage of this, creating a high-pitched sound to drive away loitering teen-agers, leaving most adults unaffected.
- **Ultrasound:** Used to make medical diagnoses, ultrasound emitters let doctors examine internal organs and developing fetuses.
- **SONAR:** Sound waves bounce off of objects, and SONAR uses this property for underwater object location and navigation.
- **Extracorporeal Shock Wave Lithotripsy (ESWL):** This is a fancy term for using

powerful sound waves to break up kidney stones.

- **Sonic Screwdriver:** In the BBC television series "Doctor Who," the Doctor uses a screwdriver that emits sonic impulses to do just about anything.

Lots More Information

Related Articles

- How Hearing Works
- How Speakers Work
- How Riot Control Works
- How Surround Sound Works
- How Guitars Work
- How Electric Guitars Work
- What's a decibel, and what is the loudest sound I can hear before it hurts my ears?

More Great Links

- LRAD Corporation
- Acoustics.org: Acoustical FAQs & Tutorials
- The Soundry: Physics of Sound
- University of Georgia Hyperphysics
- Non-Lethal Weapons

Sources

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